ORIGINAL ARTICLE

Comparison of values of traditionally measured venous bicarbonate with calculated arterial bicarbonate in intensive care unit patients of a hospital in a third-world country

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ABSTRACT

Background: Measurement of serum or plasma bicarbonate (HCO_3^-) from a sample of peripheral venous blood is routinely practiced in hospital patient managements. HCO_3^- status can also be obtained by a simple calculation during blood gas analysis requiring arterial blood as sample which is cumbersome for both patient and doctor. This study compared the measured bicarbonate levels with calculated arterial values in intensive care unit (ICU) patients to determine whether traditionally measured venous HCO_3^- and calculated HCO_3^- values [from arterial blood gas (ABG) analyzers] can be used interchangeably. **Materials and Methods:** This prospective study was carried out at a tertiary care teaching hospital in Dhaka, the capital of Bangladesh. A total of 56 adult patients with diverse medical conditions, presenting at the ICU of the health centre were enrolled in this study when deemed by the treating physician to have an ABG analysis. Arterial and venous samples were taken as close in time as possible for gas analysis and routine blood tests. **Results:** The HCO_3^- levels from ABG and traditionally measured serum showed acceptably narrow 95% limits of agreement using the Bland-Altman method. **Conclusions:** More widely prescribed venous HCO_3^- measurements can also be a useful substitute for an expensive ABG analyzer in resource-constrained health care sectors when required. However, accuracy of venous blood in assessment of additional ABG parameters is yet to be discovered.

Key words: Blood gas analyzer, calculated bicarbonate, measured bicarbonate

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INTRODUCTION

The measurement of bicarbonate level in blood is extremely common and often provides vitally important data used in the care of critically ill patients. The bicarbonate level in blood can be directly measured or derived from calculations using the Henderson-Hasselbalch equation; mostly adopted by the blood gas analyzers.[1] Arterial blood gas (ABG) analysis is commonly performed for clinical evaluation, but the procedure has certain limitations in the form of reduced patient acceptability (because the procedure can be painful) and the potential to cause complications such as arterial injury, thrombosis with distal ischemia, hemorrhage, aneurysm formation, median nerve damage and, rarely, reflex sympathetic dystrophy.[2,3] Thus, venous blood analysis is a relatively safer procedure requiring fewer punctures and hence, reducing the risk of needle stick injury to the health care worker.

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Although various studies suggest that a venous sample is relatively accurate for acid–base assessment,[3-6] VBG analysis has not gained much acceptance as a substitute for ABG analysis. On the contrary, Bicarbonate ions make up ~ 95% of the total carbon dioxide of the plasma, and hence both of them have been used interchangeably. Most blood gas analyzers use the Henderson-Hasselbach equation to calculate bicarbonate values based on the assumption that the dissociation constant (pK) and solubility coefficient (α) are invariant. However, pK is affected by changes

in pH, ionic strength and temperature, while the values of α varies with the composition of the solution such as the presence of increased salts, proteins or lipids.[1] Therefore, the calculated bicarbonate values; irrespective of the type of sample, may have significant error under certain circumstances, making its reliability questionable. Previous studies using different statistical methods to assess the agreement between measured and calculated bicarbonate have shown conflicting results, with some studies showing good agreement,[7-10] while some studies showed otherwise.[11-13]

So far this study is concerned; the feasibility of such expensive procedure in a middle income country like ours is intended to be reconsidered. However, nearly all medical centers in Bangladesh have the traditional laboratory methods to determine the concentrations of this key analyte in routine venous blood. But arterial blood gas analyzers are still limited to a small number of referral hospitals. This study was aimed to investigate the extent of agreement between arterial and venous bicarbonate levels for a group of intensive care unit (ICU) patients to determine whether measured serum HCO_3^- from traditional peripheral venous blood and calculated HCO_3^- values (from ABG analyzers) can be used interchangeably.

MATERIALS AND METHODS

This prospective study was conducted in the intensive care unit of a tertiary care teaching hospital of central Bangladesh, between July and December 2011. A total of 56 patients deemed by their treating doctor to require blood gas analysis either during initial evaluations or as part of their clinical care in ICU were included in this study. After having the study explained, a verbal consent was obtained from the patient or the relative. The study obtained 63 matched sample pairs from these 56 patients; 34 males, 27 females, mean age 53.7 ranging from 29 to 70 years. The presenting diagnosis of the patients was: acute respiratory distress (30.1%), acute coronary syndrome (26.9%), acute or chronic renal failure (20.6%), post-operative sepsis (17.4%) and other suspected metabolic derangements (4.7%). Samples for arterial blood gas analysis were obtained either by a registered nurse or a doctor. The peripheral venous samples collected at the time of intravenous line insertion or as per recommendation used for other relevant blood tests were used. Multiple samples from the same patient at different dates were also accepted.

Calculated HCO_3– concentrations were obtained from arterial blood gas samples using a Roche OPTI CCA op39090 instrument, which calculates the HCO_3^- concentration from the arterial pH and CO_2 partial pressure. The HCO_3^- concentration was directly measured in the venous serum or plasma by means of ion-selective electrodes (ISE). The samples were analyzed as quickly as possible using the blood gas analyzer; routinely practiced in the ICU. Data were analyzed using SPSS version 12 and MedCal for Windows. Pearson correlation and Bias plot (Bland and Altman)[14] method was used to compare the three measurements.

RESULTS

The HCO_3^- levels measured in venous serum showed higher values in contrast to the calculated ones (ranges 21.6 - 37.1 vs 19.8-35.3). The statistical analysis with chi square test resulted in insignificant differences (Chi-square = 0.381, p= 0.826) among the sample group frequencies based on their differences in values [Table 1].

The values shared highly significant correlation ($P < 0.001$; r = 0.987) when compared with Pearson correlation test and Bland and Altman method [Table 2]. The bias plot [Figure 1] demonstrates acceptable but poor degree of agreement for the values of bicarbonate (mmol/L) measured in venous serum vs calculated from Arterial Blood Gas analysis.

Table 1: Distribution of differences between measured (venous serum or plasma) and calculated (arterial blood gas) HCO_3^- values

Differences in values (mmol/L)	Samples, *n* (%)	Measured HCO_3^- (mmol/L)		Calculated HCO_3^- (mmol/L)	
		Minimum	Maximum	Minimum	Maximum
0-<1	21 (33.3)	21.6	29.9	21.0	29.1
1-1.99	23 (36.5)	22.3	37.1	21.2	35.3
2-2.99	19 (30.2)	21.8	31.2	19.8	29.1

Table 2: Comparison between the measured (venous serum) and calculated (arterial blood gas) HCO_3^- values

	Mean ± SD (mmol/L)	Pearson correlation, r (p)	Mean difference (SD) (mmol/L)	Bland – Altman 95% limits of agreement (mmol/L)
Calculated Arterial HCO_3^-	26.2±4.06	0.987 (0.001)	1.5 (0.69)	−0.13 to −2.89
Measured venous HCO_3^-	27.68±4.23			

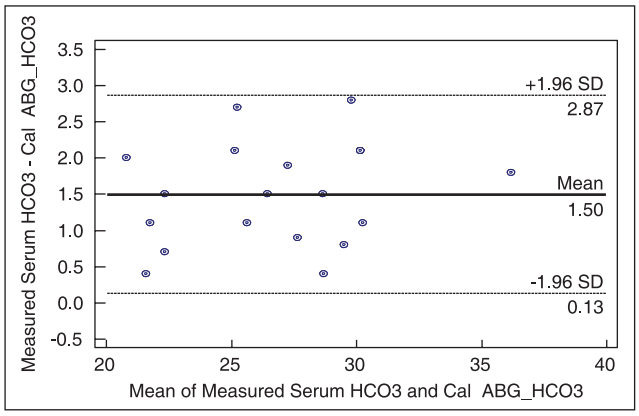

Figure 1: Bias plot comparing measured venous serum vs calculated arterial blood gas $HCO3^-$ (Cal ABG: calculated arterial blood gas HCO_3^-)

DISCUSSION

An important part of the assessment of the clinical status and progress of critically ill patients is timely assessment of acid–base status which is invariably practiced in arterial blood when it comes to blood gas analyzer. However, it may not always be practical to obtain arterial samples, particularly in the early stages of resuscitation. Besides, such sophisticated device demands careful handling and adequate maintenance raising the cast of analysis. An ample evidence is available on agreement in ABG and VBG values but it does not reduce the cast load over a patient.[3-5,15,16] So, this study was intended to focus on the unseen burdens over patient as well as the health care institutes and to look for a relatively easy, price-worthy and more specific measures.

The agreement or discrepancy between measured and calculated bicarbonate and whether both can be used interchangeably has long been discussed since the 80's,[9,10,17-19] without any concrete conclusion. With the advancement in the methodology, this issue seemed to have resurfaced, with a couple of articles published since 2008.[6-8,20,21]

The correlation coefficient between the measured and calculated bicarbonate revealed a good correlation ($r = 0.987$, $P < 0.001$). However, the use of correlation coefficient alone to assess the agreement between two methods may not be appropriate, as correlation depends on the range of values in the sample; a wide range of values like ours will yield a high correlation coefficient. Therefore, values which seem to be in poor agreement can produce high correlations provided the range is wide enough. Now, using Bland-Altman analysis, this study exhibited excellent agreement in the bicarbonate values. According to the Bland-Altman analysis significant degree of agreement was found between measured serum versus ABG bicarbonate estimates,[7-10] respectively, unlike a few.[11-13] However, such comparisons of measured and calculated HCO_3^- values can be used to detect errors in the collection or analysis of blood samples.

CONCLUSIONS

According to the study results traditionally measured venous bicarbonate can be a convenient substitute for calculated arterial bicarbonate in critically ill ICU patients. However, more accurate assessments will require ABG for additional parameters. Besides, the present study design did not involve collection of data on patient demographics, severity of illness, and requirement for inotropic support or prognosis. Detailed data, allowing analyses that include these potentially important variables might be focused in future large scale studies to add more to it.

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